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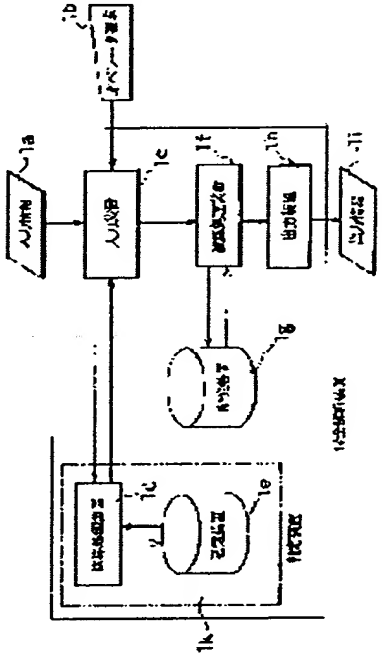
(54) MAINTENANCE ANALYSIS METHOD AND ITS DEVICE FOR LARGE-SCALE SYSTEM

(57)Abstract:
PURPOSE: To plan an optimum maintenance plan by analyzing a fault tree, obtaining the significance of respective equipments in a system or an influence degree against the system and deciding the maintenance plan of the respective equipments based on significance or the influence degree.
CONSTITUTION: Equipments and parts information, fault and maintenance history information 1a and request instruction information 1b of an operator are inputted to an input device 1c. A judgement device 1k executes the fault tree analysis of a plant being a maintenance object by an operation processor 1d in accordance with operator information 1b based on related information required for fault tree analysis, which is previously stored in a storage device 1e. Information inputted to the input device 1c is stored in a storage device 1g through an operation processor 1f. The stored content is operated by the operation processor 1f based on request/indication information 1b of the operator, is outputted/ displayed from an output device 1h and the operator can obtain output information 1i.



[TITLE OF THE INVENTION]

Maintenance Analysis Method for Large-Scale System and Apparatus for Same

[ABSTRACT]

[Purpose] To prepare an optimal maintenance plan without using history data.

[Configuration] In a maintenance analysis for a large-scale system composed of a large number of apparatuses, a fault tree analysis is applied to the configuration of the large-scale system thereby to estimate the importance of each apparatus in the system or the influence on the system, whereby a maintenance plan for each apparatus is determined on the basis of the importance or the influence.

[CLAIMS]

[Claim 1] A maintenance analysis method for a large-scale system composed of a large number of apparatuses, wherein a fault tree analysis is applied to the configuration of said large-scale system thereby to estimate the importance of each apparatus in said system or the influence on said system, whereby a maintenance plan for each apparatus is determined on the basis of said importance or said influence.

[Claim 2] A maintenance analysis method for a large-scale system composed of a plurality of subsystems each performing a group of functions, wherein a fault tree analysis is applied to the configuration of said large-scale system thereby to estimate the importance or the influence of each subsystem, whereby a maintenance plan for each subsystem is determined on the basis of said importance or said influence.

[Claim 3] A maintenance analysis method for a large-scale system according to claim 1 or 2, wherein said maintenance plan includes at least one selected from the group consisting of the necessity or dispensability of maintenance, the priority in the order of maintenance, and the scheme of maintenance.

[Claim 4] A maintenance analysis method for a large-scale system according to any one of claims 1-3, wherein said importance or said influence is estimated quantitatively in said fault tree analysis.

[Claim 5] A maintenance analysis method for a large-scale system according to any one of claims 1-4, wherein said large-scale system is composed of one of a power generation plant, a chemical plant, an iron and steel plant, and a general industrial plant.

[Claim 6] A maintenance analysis method for a large-scale system according to

any one of claims 1-5, wherein a maintenance plan is determined using the data of said importance or said influence estimated in said fault tree analysis in a design stage of said large-scale system.

[Claim 7] A maintenance analysis apparatus for a large-scale system composed of a large number of apparatuses, comprising: analyzing means for applying a fault tree analysis to the configuration of said large-scale system and thereby estimating the importance of each apparatus in said system or the influence on said system; and maintenance determining means for determining a maintenance plan for each apparatus on the basis of said importance or said influence.

[Claim 8] A maintenance analysis apparatus for a large-scale system composed of a plurality of subsystems each performing a group of functions, comprising: analyzing means for applying a fault tree analysis to the configuration of said large-scale system and thereby estimating the importance or the influence of each subsystem; and maintenance determining means for determining a maintenance plan for each subsystem on the basis of said importance or said influence.

[Claim 9] A maintenance analysis apparatus for a large-scale system according to claim 7 or 8, wherein said maintenance plan includes at least one selected from the group consisting of the necessity or dispensability of maintenance, the priority in the order of maintenance, and the scheme of maintenance.

[Claim 10] A maintenance analysis apparatus for a large-scale system according to any one of claims 7-9, wherein said importance or said influence is estimated quantitatively in said fault tree analysis.

[Claim 11] A maintenance analysis apparatus for a large-scale system according to any one of claims 7-10, wherein said large-scale system is composed of one of a power generation plant, a chemical plant, an iron and steel plant, and a general industrial plant.

[Claim 12] A maintenance analysis apparatus for a large-scale system according to any one of claims 7-11, wherein said maintenance determining means determines a maintenance plan using the data of said importance or said influence estimated in a fault tree analysis in a design stage of said large-scale system, instead of using the analysis result from said analyzing means.

[DETAILED DESCRIPTION OF THE INVENTION]

[Industrial Field of Utilization]

The present invention relates generally to a maintenance analysis method for a large-scale system such as a plant, and an apparatus used for this purpose, and more specifically to a maintenance analysis method for optimally determining the necessity or dispensability of maintenance, the order of maintenance, and the scheme of maintenance for apparatuses or subsystems constituting a large-scale system, and an apparatus for used for this purpose.

[Prior Art]

In a large-scale system, such as a nuclear, thermal, or hydraulic power generation plant, a chemical plant, and an iron and steel plant, composed of a large number of apparatuses, maintenance is necessary for the apparatuses or the subsystems. In such a system, a maintenance plan needs to be prepared using a computer because a large number of apparatuses need maintenance and because these apparatuses require various maintenance methods, repair methods, and the like different from each other.

A prior art method of maintenance of a large-scale system is described in Japanese Laid-Open Patent Publication No. Hei3-285118. In this prior art method, preventive maintenance is performed on the basis of the remaining life of the apparatuses constituting the system. In another prior art method described in Japanese Laid-Open Patent Publication No. Hei3-90892, data on past accidents and faults is stored in a storage apparatus, whereby occurrence of similar accidents and the like is avoided using the database. In further another prior art method described in Japanese Laid-Open Patent Publication No. Hei4-147014, the states of apparatuses are monitored, whereby the monitored data is stored in a storage apparatus, and whereby the apparatuses are maintained on the basis of the monitored data.

[Problems to be Solved by the Invention]

In preparing a maintenance plan for a large-scale system, it is not very practical to prepare a maintenance plan on the basis of the monitored state data or the data on past accidents and the like as in the above-mentioned prior art methods. That is, the above-mentioned methods are difficult to apply to existing plants. This is because although small accidents and the like occur in such plants presently operating in various locations, substantial accidents seldom occur. Accordingly, seldom available is reference data to be used for preparing optimal maintenance plans. Consequently, instead of a method of preparing maintenance plans on the basis of history data or on the basis of the state data of presently operating apparatuses, another method is

desired for preparing optimal maintenance plans.

An object of the invention is to provide a maintenance analysis method for preparing an optimal maintenance plan without using history data or the like, and an apparatus used for this purpose.

[Means for Solving the Problem]

In a maintenance analysis for a large-scale system composed of a large number of apparatuses, a fault tree analysis is applied to the configuration of the large-scale system thereby to estimate the importance of each apparatus in the system or the influence on the system, whereby a maintenance plan for each apparatus is determined on the basis of the importance or the influence. This achieves the above-mentioned object.

[Operation of the Invention]

A fault tree analysis is applied to system configuration data obtained when the system was designed, whereby a maintenance plan is prepared on the basis of the analysis result. Accordingly, the maintenance plan is prepared independently on history data or the present states of apparatuses. Further, the maintenance plan is applicable directly to a presently operating plant or the like.

[Embodiments of the Invention] An embodiment of the invention is described below with reference to the drawings. In the embodiment of the invention described below, in order to select apparatuses or subsystems to be maintained, and thereby to determine their priority, a fault tree analysis is used for judging whether a fault for each apparatus or subsystem causes a fatal fault to the entire system or not. (In the fault tree analysis, an expected system fault is set as a top event. Then, fault factors in the system component apparatuses possibly leading to the top event are expanded in the shape of a tree using logic symbols. Accordingly, the occurrence probability of the top event and the resulting unavailability rate are calculated on the basis of quantitative data such as failure rates and repair times for the factors.) This permits quantitative analysis of the influence on the system caused by a fault in each apparatus, and further permits automatic judgment whether the fault is fatal to the system or not. Accordingly, apparatuses and subsystems to be maintained are selected appropriately. Further, since the obtained result of analysis is quantitative information, priority in the order of maintenance is determined on the basis of the influence and importance on the large-scale system such as a plant.

In order to determine an optimal maintenance scheme in the next step,

information on the apparatuses to be maintained and the priority in the order of maintenance is set in a predetermined logic procedure for determining the maintenance scheme depending on the characteristics of the system or plant. A final and optimal maintenance scheme is judged and determined according to this logic procedure. In order to perform these procedures, facility information (functions, fault modes, fault rates, used times, and the like) prepared in advance for the apparatuses or the subsystems is stored as electronic or magnetic information in a storage apparatus. Then, the information is read out and processed automatically. This permits even unskilled persons to prepare appropriate maintenance plans. Even in case that the system is modified partially, merely a correction in the fault tree permits immediate analysis of the importance and the influence of the modified portion of the system.

Figure 1 is a configuration diagram of a maintenance analysis apparatus according to an embodiment of the invention. Information 1a such as information on apparatuses and components and information on the fault and maintenance history is inputted into the input apparatus 1c, together with the information 1b of operator's requests and directions. In a judgment apparatus 1k, on the basis of relevant information which is stored in a storage apparatus 1e in advance and which is used in a fault tree analysis, an operation processor 1d performs a fault tree analysis for the plant to be maintained, depending on the above-mentioned operator information 1b. The analysis result from the judgment apparatus 1k is also inputted to the input apparatus 1c.

The information inputted to the input apparatus 1c is stored in a storage apparatus 1g via an operation processor 1f. The contents stored in the storage apparatus 1g is operated by the processor 1f depending on the information 1b of operator's requests and directions. The result is then outputted and displayed by an output apparatus 1h, so that the operator obtains output information 1i.

Figure 2 is a function diagram of the judgment apparatus 1k shown in Figure 1. An operation processor 1d expands logic symbols on the basis of the relevant information (that is, apparatus fault rates 2c, unexpanded event occurrence probabilities 2d, intermediate events 2e, evaluation times 2f, logic symbols 2g, and an FT logic procedure 2h) stored in the storage apparatus 1e and used in the fault tree analysis. The operation processor 1d thereby generate a fault tree the top event of which is the functional failure of the system or the stoppage of the plant. In the fault tree, each intermediate event directly causing the top event is expanded sequentially into basic

events in respective functional units or subsystems and into unexpanded events which are external factors or human errors. Each of the basic events and the unexpanded events is processed in logic operation using numerical data on the basis of the values 2c, 2d, and 2f stored in the storage apparatus 1e in advance.

As a result, obtained is a minimal cut set (minimal bus set) 2i which is a combination of the respective events. At the same time, the occurrence probability of the top event (system fault probability) 2j is calculated. On the basis of the minimal cut set, the operation processor 1d performs importance evaluation 2k for each event. This importance evaluation provides Birnbaum importance 2l, criticality importance 2m, risk achievement worth 2o, and risk reduction worth 2p.

The Birnbaum importance 2l indicates sensitivity of the occurrence probability of the top event relative to the occurrence probability of each basic event. From the engineering point of view, the Birnbaum importance indicates the degree of influence on the system caused by a fault in each apparatus, and is calculated according to the following Formula 1.

$$Bli = \lim_{\delta q \to O} (\delta Q / \delta q) \quad \cdots(1)$$

with

Bli: Birnbaum importance,

δ Q: variation of the occurrence probability of the top event, and

δ q: variation of the occurrence probability of a basic event i.

The criticality importance 2m is a relative variation ratio of the occurrence probability of the top event to the variation width of the occurrence probability of the basic event, and is calculated according to the following Formula 2.

$$C1i = q/Q \times B1i \quad \cdots(2)$$

with

Cli: criticality importance,

q: occurrence probability of a basic event i,

Q: occurrence probability of the top event, and

Bli: Birnbaum importance.

The risk achievement worth 2o indicates the degree of contribution to an increase in the occurrence probability of system fault (or the unavailability) when the fault occurrence probability of a basic event (or a group of basic events) i is assumed to be unity. That is, the risk achievement worth 2o provides an indication of the degree

of system degradation, and is calculated according to the following Formula 3.

Risk achievement worth = g(Ii, x)/g(x) > 1.0 ···(3)

with

g(Ii, x): occurrence probability of system fault (or unavailability) when the fault rate of a basic event (or a group of basic events) i is assumed to be 1.0, and

g(x): occurrence probability of system fault (or unavailability).

The risk reduction worth 2p indicates the degree of contribution to a reduction in the occurrence probability of system fault (or the unavailability) when the fault occurrence probability of a basic event (or a group of basic events) i is assumed to be zero. That is, the risk reduction worth 2p provides an indication of the degree of system improvement, and is calculated according to the following Formula 4.

Risk reduction worth = g(x)/ g(Oi, x) ···(4)

with

g(Oi, x): occurrence probability of system fault (or unavailability when the fault rate of a basic event (or a group of basic events) i is assumed to be 0, and

g(x): occurrence probability of system fault (or unavailability).

On the basis of the order of the values 2l, 2m, 2o, and 2p for each apparatus or subsystem, the operation processor 1d determines the overall priority of each apparatus or subsystem. On the basis of this final and overall priority, the apparatuses or subsystems configured in functional units are classified into two groups "requiring maintenance" and "not requiring maintenance" according to a predetermined threshold. The threshold used here is the median value or the mean value for all the apparatuses or subsystems within the system or the plant. As for the apparatuses or subsystems belonging to the group "requiring maintenance", their priority in the order of maintenance is determined again on the basis of the importance evaluation result 2k. As a result, the apparatuses or subsystems which are configured in functional units and which cause possibly a fatal fault to the system (or plant) are maintained in the descending order of the influence or the importance.

Figure 3 is a functional configuration diagram of the operation processor 1f shown in Figure 1. As for support information for determining the maintenance scheme, on the basis of the operator's request and direction information 1b, information (data for determining the maintenance scheme) 3a stored in the storage apparatus 1g is searched via an I/O processing function 3b by a searching function 3c, and thereby

provided to a maintenance scheme determining function 3e, together with the information of judgment result 3d obtained from the judgment apparatus 1k. The result 3f determined by the maintenance scheme determining function 3e is outputted as the maintenance scheme output data 3g from the I/O processing function 3b. This maintenance scheme output data 3g specifies the optimal maintenance scheme.

Figure 4 is a flow chart illustrating an example of a logic procedure in the maintenance scheme determining function 3e shown in Figure 3. On the basis of the information obtained by the judgment apparatus 1k, the logic procedure shown in Figure 4 is performed on each apparatus to be maintained in the descending order of the influence or the importance, as follows.

(1) Is it possible and effective to detect and then repair a fault of the apparatus before the fault causes a functional influence?

(2) Is it possible and effective to inspect and detect a fault state?

(3) Is it possible and effective to perform regular maintenance in order to minimize the fault rate?

(4) Is it possible and effective to perform regular replacement in order to prevent faults and minimize the fault rate?

(5) Does a fault influence on the plant?

(6) Is a redesign or a design change possible?

"Inspection and state monitoring maintenance" is determined to be carried out for the apparatus judged as effective in step (1). "Inspection" is carried out for the apparatus judged as effective in step (2). "Regular maintenance" is carried out for the apparatus judged as effective in step (3). "Age-based maintenance" is determined for the apparatus judged as effective in step (4). "Ordinary posterior maintenance" is carried out for the apparatus judged as not influencing in step (5). "Redesign or design change" is carried out for the apparatus judged as possible in step (6). "Emergency posterior maintenance" is carried out for the other apparatuses. The results of the determination are outputted by the I/O processing function 3b shown in Figure 3.

The logic procedure shown in Figure 4 is merely illustrative, and hence another logic procedure may be used. For example, "the possibility of detection by an operator", "the presence or absence of an appropriate preventive maintenance service", or the like may be judged in the logic procedure. Finally, time scheduled maintenance and state monitoring maintenance each serving as preventive maintenance are set.

Regular maintenance, age-based maintenance, and the like are set in the time scheduled maintenance, while emergency maintenance and ordinary posterior maintenance are set in the posterior maintenance.

Figure 5 shows an example of the output result of the judgment of the necessity or dispensability of apparatus maintenance. Figure 6 shows an example of the output of the determination of the priority in the order of maintenance obtained on the basis of the importance evaluation results. Figure 7 shows an example of the output of the maintenance schemes determined according to the logic procedure shown in Figure 4. As shown in these output results, the optimal priority in the order of maintenance and the optimal maintenance schemes are determined for the apparatuses or subsystems to be maintained, even by an unskilled person using minimum personnel resources.

In the above-mentioned embodiment, a fault tree analysis was performed in the maintenance analysis apparatus thereby to have determined a maintenance scheme and the like. However, in case that a fault tree analysis has already been performed at the stage of system design or plant design and that a maintenance scheme has been determined on the basis of the importance and the like of apparatus, a maintenance plan may be prepared using the results of the analysis.

[Effects of the Invention]

According to the invention, the evaluating management of apparatuses or subsystems reduces faults and problems, avoids possible faults, and thereby improves the reliability of the system (plant) Accordingly, the availability rate of the system (plant) is improved, and the maintenance cost is reduced.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Figure 1]

Figure 1 is a configuration diagram of a maintenance analysis apparatus according to an embodiment of the invention.

[Figure 2]

Figure 2 is a function diagram of the judgment apparatus shown in Figure 1.

[Figure 3]

Figure 3 is a functional configuration diagram of the operation processor 1f shown in Figure 1.

[Figure 4]

Figure 4 is a logic diagram for determining a maintenance scheme.

[Figure 5]
Figure 5 is an example of the output of the judgment results of the necessity or dispensability of apparatus maintenance.
[Figure 6]
Figure 6 is an example of the output of the determination of the priority in the order of maintenance.
[Figure 7]
Figure 7 is an example of the output of the determination of a maintenance scheme.

[Description of the Reference Numerals]
1a: Apparatus and component information, 1b: Operator's request and direction information, 1c: Input apparatus, 1d: Operation processor, 1e: Storage apparatus, 1f: Operation processor, 1g: Storage apparatus, 1h: Output apparatus, 1i: Output information, 1k: Judgment apparatus.